McGRAW-HILL DICTIONARY OF SCIENTIFIC AND TECHNICAL TERMS

Fifth Edition

Sybil P. Parker
Editor in Chief

McGraw-Hill, Inc.
New York San Francisco Washington, D.C.
Auckland Bogotá Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore Sydney Tokyo Toronto

Appendix B

On the cover: Photomicrograph of crystals of vitamin B_1.
(Dennis Kunkel, University of Hawaii)

In addition, material has been drawn from the following references: R. E. Huschke, *Glossary of Meteorology*, American Meteorological Society, 1959; *U.S. Air Farce Glassary of Standardized Terms*, AF Manual 11-1, vol. 1, 1972; *Communicatians-Electronics Terminology*, AF Manual 11-1, vol. 3, 1970; W. H. Allen, ed., *Dictionary of Technical Terms for Aerospace Use*, 1st ed., National Aeronautics and Space Administration, 1965; J. M. Gilliland, *Solar-Terrestrial Physics: A Glossary of Terms and Abbreviations*, Royal Aircraft Establishment Technical Report 67158, 1967; *Glassary of Air Traffic Control Terms*, Federal Aviation Agency; *A Glossary af Range Terminology, White Sands Missile Range, New Mexico*, National Bureau of Standards, AD 467-424; *A DOD Glossary of Mapping, Charting and Geodetic Terms*, 1st ed., Department of Defense, 1967; P. W. Thrush, comp. and ed., *A Dictlanary of Mining, Mineral, and Related Terms*, Bureau of Mines, 1968; *Nuclear Terms: A Glossary*, 2d ed., Atomic Energy Commission; F. Casey, ed., *Compilatian af Terms in Infarmation Sciences Technology*, Federal Council for Science and Technology, 1970; *Glossory af Stinfo Terminology*, Office of Aerospace Research, U.S. Air Force, 1963; *Naval Dictionary of Electronic, Technical, and Imperotive Terms*, Bureau of Naval Personnel, 1962; *ADP Glossary*, Department of the Navy, NAVSO P-3097.

McGRAW-HILL DICTIONARY OF SCIENTIFIC AND TECHNICAL TERMS,
Fifth Edition

3 4 5 6 7 8 9 0 DOW/DOW 9 9 8 7 6 5

ISBN 0-07-042333-4

Library of Congress Cataloging-in-Publication Data

McGraw-Hill dictionary of scientific and technical terms /
Sybil P. Parker, editor in chief.—5th ed.
p. cm.
ISBN 0-07-042333-4
1. Science—Dictionaries. 2. Technology—Dictionaries.
I. Parker, Sybil P.
Q123.M34 1993
503—dc20 93-34772
CIP

INTERNATIONAL EDITION

When ordering this title, use ISBN 0-07-113584-7.

Appendix B

an infinitesimal amount of solvent is added to a solution at constant pressure. Also known as differential heat of dilution. { 'hēt əv də'lü·shən }

heat of dissociation [PHYS CHEM] The increase in enthalpy at constant pressure, when molecules break apart or valence linkages rupture. { 'hēt əv di,sō·sē'ā·shən }

heat of emission [ELECTR] Additional heat energy that must be supplied to an electron-emitting surface to maintain it at a constant temperature. { 'hēt əv i'mish·ən }

heat of evaporation *See* heat of vaporization. { 'hēt əv i,vap·ə'rā·shən }

heat of formation [PHYS CHEM] The increase in enthalpy resulting from the formation of 1 mole of a substance from its elements at constant pressure. { 'hēt əv fȯr'mā·shən }

heat of fusion [THERMO] The increase in enthalpy accompanying the conversion of 1 mole, or a unit mass, of a solid to a liquid at its melting point at constant pressure and temperature. Also known as latent heat of fusion. { 'hēt əv 'fyü·zhən }

heat of hydration [PHYS CHEM] The increase in enthalpy accompanying the formation of 1 mole of a hydrate from the anhydrous form of the compound and from water at constant pressure. { 'hēt əv hī'drā·shən }

heat of ionization [PHYS CHEM] The increase in enthalpy when 1 mole of a substance is completely ionized at constant pressure. { 'hēt əv ,ī·ən·ə'zā·shən }

heat of linkage [PHYS CHEM] The bond energy of a particular type of valence linkage between atoms in a molecule, as determined by the energy required to dissociate all bonds of the type in 1 mole of the compound divided by the number of such bonds in a compound. { 'hēt əv 'liŋk·ij }

heat of mixing [THERMO] The difference between the enthalpy of a mixture and the sum of the enthalpies of its components at the same pressure and temperature. { 'hēt əv 'mik·siŋ }

heat of reaction [PHYS CHEM] **1.** The negative of the change in enthalpy accompanying a chemical reaction at constant pressure. **2.** The negative of the change in internal energy accompanying a chemical reaction at constant volume. { 'hēt əv rē'ak·shən }

heat of solidification [THERMO] The increase in enthalpy when 1 mole of a solid is formed from a liquid or, less commonly, a gas at constant pressure and temperature. { 'hēt əv sə,lid·ə·fə'kā·shən }

heat of solution [PHYS CHEM] The enthalpy of a solution minus the sum of the enthalpies of its components. Also known as integral heat of solution; total heat of solution. { 'hēt əv sə'lü·shən }

heat of sublimation [THERMO] The increase in enthalpy accompanying the conversion of 1 mole, or unit mass, of a solid to a vapor at constant pressure and temperature. Also known as latent heat of sublimation. { 'hēt əv ,səb·lə'mā·shən }

heat of transformation [THERMO] The increase in enthalpy of a substance when it undergoes some phase change at constant pressure and temperature. { 'hēt əv ,tranz·fər'mā·shən }

heat of vaporization [THERMO] The quantity of energy required to evaporate 1 mole, or a unit mass, of a liquid, at constant pressure and temperature. Also known as enthalpy of vaporization; heat of evaporation; latent heat of vaporization. { 'hēt əv ,vā·pə·rə'zā·shən }

heat of wetting [THERMO] **1.** The heat of adsorption of water on a substance. **2.** The additional heat required, above the heat of vaporization of free water, to evaporate water from a substance in which it has been absorbed. { 'hēt əv 'wed·iŋ }

heat pipe [ENG] A heat-transfer device consisting of a sealed metal tube with an inner lining of wicklike capillary material and a small amount of fluid in a partial vacuum; heat is absorbed at one end by vaporization of the fluid and is released at the other end by condensation of the vapor. { 'hēt ,pīp }

heat pump [MECH ENG] A device which transfers heat from a cooler reservoir to a hotter one, expending mechanical energy in the process, especially when the main purpose is to heat the hot reservoir rather than refrigerate the cold one. { 'hēt ,pəmp }

heat quantity [THERMO] A measured amount of heat; units are the small calorie, normal calorie, mean calorie, and large calorie. { 'hēt ¦kwän·əd·ē }

heat radiation [THERMO] The energy radiated by solids, liquids, and gases in the form of electromagnetic waves as a result of their temperature. Also known as thermal radiation. { 'hēt ,rād·ē'ā·shən }

heat rash *See* miliaria. { 'hēt ,rash }

heat rate [MECH ENG] An expression of the conversion efficiency of a thermal power plant or engine, as heat input per unit of work output; for example, Btu/kWh. { 'hēt ,rāt }

heat reactor [NUCLEO] A nuclear reactor designed primarily to supply heat for industrial purposes. { 'hēt rē'ak·tər }

heat release [THERMO] The quantity of heat released by a furnace or other heating mechanism per second, divided by its volume. { 'hēt ri,lēs }

heat resistance *See* thermal resistance. { 'hēt ri,zis·təns }

heat-resistant alloy [MET] An oxidation-resistant alloy. { 'hēt ri,zis·tənt 'al,ȯi }

heat-resistant glass [MATER] Glass, such as borosilicate glass, that is heat-treated or leached to remove alkali so that it withstands high heat and sudden cooling without shattering. { 'hēt ri,zis·tənt 'glas }

heat run [ELEC] A series of temperature measurements made on an electric device during operating tests under various conditions. { 'hēt ,rən }

heat seal [ENG] A union between two thermoplastic surfaces by application of heat and pressure to the joint. { 'hēt ,sēl }

heatseeker [ORD] A guided missile incorporating an infrared device for homing on heat-radiating machines or installations, such as an aircraft engine or a blast furnace. { 'hēt ,sēk·ər }

heat set [TEXT] A process to fix or set a crimp or texture in yarn by use of heat. { 'hēt ,set }

heat shield [MATER] Any protective layer that gives protection from heat; used on the front of a reentry capsule. { 'hēt ,shēld }

heat shock protein [MOL BIO] Any of a group of proteins that are synthesized in the cytoplasm of cells as part of the heat shock response and act to protect the chromosomes from damage. { ¦hēt ,shäk 'prō,tēn }

heat shock response [MOL BIO] A cellular reaction to a stimulus such as elevated temperatures or abrupt environmental changes, in which there is cessation or slowdown of normal protein synthesis and activation of previously inactive genes, resulting in the production of heat shock proteins. { 'hēt ,shäk ri,späns }

heat-shrinkable tubing [MATER] A type of plastic tubing that can be heated and shrink-fitted over terminals and other objects of varying sizes and shapes, for insulating and other purposes. { 'hēt ¦shriŋk·ə·bəl 'tüb·iŋ }

heat shunt [MET] A heatsink placed in contact with the lead of a delicate component to prevent overheating during soldering. { 'hēt ,shənt }

heatsink [AERO ENG] **1.** A type of protective device capable of absorbing heat and used as a heat shield. **2.** In nuclear propulsion, any thermodynamic device, such as a radiator or condenser, that is designed to absorb the excess heat energy of the working fluid. Also known as heat dump. [ELEC] A mass of metal that is added to a device for the purpose of absorbing and dissipating heat; used with power transistors and many types of metallic rectifiers. Also known as dissipator. [THERMO] Any (gas, solid, or liquid) region where heat is absorbed. { 'hēt,siŋk }

heatsink cooling [ENG] Cooling a body or system by allowing heat to be absorbed from it by another body. { 'hēt,siŋk ¦kül·iŋ }

heat source [THERMO] Any device or natural body that supplies heat. { 'hēt ,sȯrs }

heat sterilization [ENG] An act of destroying all forms of life on and in bacteriological media, foods, hospital supplies, and other materials by means of moist or dry heat. { 'hēt ,ster·ə·lə'zā·shən }

heat storage [OCEANOGR] The tendency of the ocean to act as a heat reservoir; results in smaller daily and annual variations in temperature over the sea. { 'hēt ,stȯr·ij }

heat stress index [PHYSIO] Relation of the amount of evaporation or perspiration required for particular job conditions as related to the maximum evaporative capacity of an average person. Abbreviated HSI. { 'hēt ,stres ¦in,deks }

heatstroke [MED] A heat-exposure syndrome characterized by hyperpyrexia and prostration due to diminution or cessation of sweating, occurring most commonly in persons with underlying disease. { 'hēt,strōk }

heat thunderstorm [METEOROL] In popular terminology, a

Heat pipe

From Wikipedia, the free encyclopedia

A laptop heat pipe system

A **heat pipe** or **heat pin** is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces.

At the hot interface within a heat pipe, which is typically at a very low pressure, a liquid in contact with a thermally conductive solid surface turns into a vapor by absorbing heat from that surface. The vapor condenses back into a liquid at the cold interface, releasing the latent heat. The liquid then returns to the hot interface through either capillary action or gravity action where it evaporates once more and repeats the cycle. In addition, the internal pressure of the heat pipe can be set or adjusted to facilitate the phase change depending on the demands of the working conditions of the thermally managed system.

Contents

Structure, design and construction

A typical heat pipe consists of a sealed pipe or tube made of a material with high thermal conductivity such as copper or aluminium at both hot and cold ends. A vacuum pump is used to remove all air from the empty heat pipe, and then the pipe is filled with a fraction of a percent by volume of *working fluid* (or coolant) chosen to match the operating temperature. Examples of such fluids include water, ethanol, acetone, sodium, or mercury. Due to the partial vacuum that is near or below the vapor pressure of the fluid, some of the fluid will be in the liquid phase and some will be in the gas phase. The use of a vacuum eliminates the need for the working gas to diffuse through any other gas and so the bulk transfer

Appendix B

of the vapor to the cold end of the heat pipe is at the speed of the moving molecules. In this sense, the only practical limit to the rate of heat transfer is the speed with which the gas can be condensed to a liquid at the cold end.[1]

Inside the pipe's walls, an optional wick structure exerts a capillary pressure on the liquid phase of the working fluid. This is typically a sintered metal powder or a series of grooves parallel to the pipe axis, but it may be any material capable of exerting capillary pressure on the condensed liquid to wick it back to the heated end. The heat pipe may not need a wick structure if gravity or some other source of acceleration is sufficient to overcome surface tension and cause the condensed liquid to flow back to the heated end. [citation needed]

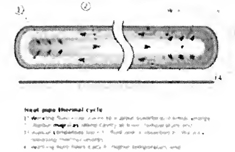
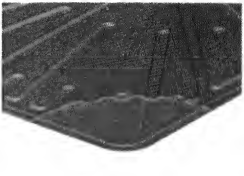


Diagram showing components and mechanism for a heat pipe containing a wick

A heat pipe is not a thermosiphon, because there is no siphon. Thermosiphons transfer heat by single-phase convection. (See also: Perkins tube, after Jacob Perkins.)



Cut-away view of a 500 µm thick flat heat pipe, with a thin planar capillary (aqua colored)

Heat pipes contain no mechanical moving parts and typically require no maintenance, though non-condensing gases (that diffuse through the pipe's walls, result from breakdown of the working fluid, or exist as impurities in the materials) may eventually reduce the pipe's effectiveness at transferring heat. This is significant when the working fluid's vapour pressure is low.[citation needed]

The materials chosen depend on the temperature conditions in which the heat pipe must operate, with coolants ranging from liquid helium for extremely low temperature applications (2–4 K) to mercury (523–923 K) & sodium (873–1473 K) and even indium (2000–3000 K) for extremely high temperatures. The vast majority of heat pipes for low temperature applications use some combination of ammonia (213–373 K), alcohol (methanol (283–403 K) or ethanol (273–403 K)) or water (303–473 K) as working fluid. Since the heat pipe contains a vacuum, the working fluid will boil and hence take up latent heat at well below its boiling point at atmospheric pressure. Water, for instance, will boil at just above 273 K (0 degrees Celsius) and so can start to effectively transfer latent heat at this low temperature.[citation needed]

Thin flat heat pipe (heat spreader) with remote heat sink and fan

The advantage of heat pipes over many other heat-dissipation mechanisms is their great efficiency in transferring heat. They are a fundamentally better heat conductor than an equivalent cross-section of solid copper (a heat sink alone, though simpler in design and construction, does not take advantage of the principle of matter phase transition). Some heat pipes have demonstrated a heat flux of more than 230 MW/m², nearly four times the heat flux at the surface of the sun.[2]

Appendix B

Active control of heat flux can be effected by adding a variable volume liquid reservoir to the evaporator section. Variable conductance heat pipes employ a large reservoir of inert immiscible gas attached to the condensing section. Varying the gas reservoir pressure changes the volume of gas charged to the condenser which in turn limits the area available for vapor condensation. Thus a wider range of heat fluxes and temperature gradients can be accommodated with a single design.

A modified heat pipe with a reservoir having no capillary connection to the heat pipe wick at the evaporator end can also be used as a thermal diode. This heat pipe will transfer heat in one direction, acting as an insulator in the other.[citation needed]

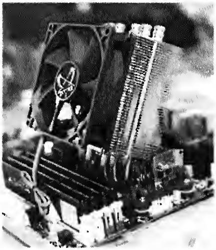
Vapor Chamber or Flat heat pipes

Thin planar heat pipes (heat spreaders) have the same primary components as tubular heat pipes. These components are a hermetically sealed hollow vessel, a working fluid, and a closed-loop capillary recirculation system.

Compared to a one-dimensional tubular heat pipe, the width of a two-dimensional heat pipe allows an adequate cross section for heat flow even with a very thin device. These thin planar heat pipes are finding their way into "height sensitive" applications, such as notebook computers, and surface mount circuit board cores. It is possible to produce flat heat pipes as thin as 0.5 mm (thinner than a credit card).[citation needed]

Heat transfer

Heat pipes employ evaporative cooling to transfer thermal energy from one point to another by the evaporation and condensation of a working fluid or coolant. Heat pipes rely on a temperature difference between the ends of the pipe, and cannot lower temperatures at either end beyond the ambient temperature (hence they tend to equalise the temperature within the pipe).



A heat sink (aluminium) with heat pipe (copper)

When one end of the heat pipe is heated the working fluid inside the pipe at that end evaporates and increases the vapour pressure inside the cavity of the heat pipe. The latent heat of evaporation absorbed by the vaporisation of the working fluid reduces the temperature at the hot end of the pipe.

The vapour pressure over the hot liquid working fluid at the hot end of the pipe is higher than the equilibrium vapour pressure over condensing working fluid at the cooler end of the pipe, and this pressure difference drives a rapid mass transfer to the condensing end where the excess vapour condenses, releases its latent heat, and warms the cool end of the pipe. Non-condensing gases (caused by contamination for instance) in the vapour impede the gas flow and reduce the effectiveness of the heat pipe, particularly at low temperatures, where vapour pressures are low. The velocity of molecules in a gas is approximately the speed of sound and in the absence of non condensing gases, this is the upper velocity with which they could travel in the heat pipe. In practice, the speed of the vapour through the heat pipe is dependent on the rate of condensation at the cold end.[citation needed]

Appendix B

The condensed working fluid then flows back to the hot end of the pipe. In the case of vertically-oriented heat pipes the fluid may be moved by the force of gravity. In the case of heat pipes containing wicks, the fluid is returned by capillary action.

When making heat pipes, there is no need to create a vacuum in the pipe. One simply boils the working fluid in the heat pipe until the resulting vapour has purged the non condensing gases from the pipe and then seals the end.

An interesting property of heat pipes is the temperature over which they are effective. Initially, it might be suspected that a water charged heat pipe would only work when the hot end reached the boiling point (100 °C) and steam was transferred to the cold end. However, the boiling point of water is dependent on absolute pressure inside the pipe. In an evacuated pipe, water will boil just slightly above its melting point (0 °C). The heat pipe will operate, therefore, when the hot end is just slightly warmer than the melting point of the working fluid. Similarly, a heat pipe with water as a working fluid can work well above the boiling point (100 °C), if the cold end is low enough in temperature to condense the fluid. [*citation needed*]

The main reason for the effectiveness of heat pipes is the evaporation and condensation of the working fluid. The heat of vaporization greatly exceeds the sensible heat capacity. Using water as an example, the energy needed to evaporate one gram of water is equivalent to the amount of energy needed to raise the temperature of that same gram of water by 540 °C (hypothetically, if the water was under extremely high pressure so it didn't vaporize or freeze over this temperature range). Almost all of that energy is rapidly transferred to the "cold" end when the fluid condenses there, making a very effective heat transfer system with no moving parts.[*citation needed*]

Origins and research in the United States

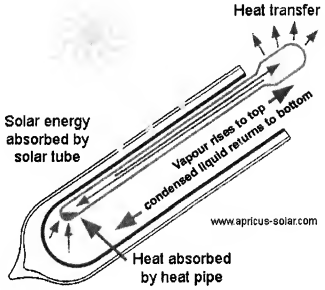
The general principle of heat pipes using gravity (commonly classified as two phase thermosiphons) dates back to the steam age. The modern concept for a capillary driven heat pipe was first suggested by R.S. Gaugler of General Motors in 1942 who patented the idea.[3] The benefits of employing capillary action were independently developed and first demonstrated by George Grover at Los Alamos National Laboratory in 1963 and subsequently published in the Journal of Applied Physics in 1964.[4] Grover noted in his notebook:[5]

> "Heat transfer via capillary movement of fluids. The "pumping" action of surface tension forces may be sufficient to move liquids from a cold temperature zone to a high temperature zone (with subsequent return in vapor form using as the driving force, the difference in vapor pressure at the two temperatures) to be of interest in transferring heat from the hot to the cold zone. Such a closed system, requiring no external pumps, may be of particular interest in space reactors in moving heat from the reactor core to a radiating system. In the absence of gravity, the forces must only be such as to overcome the capillary and the drag of the returning vapor through its channels."

Between 1964 and 1966, RCA was the first corporation to undertake research and development of heat pipes for commercial applications (though their work was mostly funded by the US government). During the late 1960s NASA played a large role in heat pipe development by funding a significant amount of research on their applications and reliability in space flight following from Grover's suggestion. NASA's attraction to heat pipe cooling systems was understandable given their low weight, high heat flux, and zero power draw. Their primary interest however was based on the fact that the system wouldn't be adversely affected by operating in a zero gravity environment. The first application

Heat pipes might seem like a new concept, but you are probably using them everyday and don't even know it. Laptop computers often using small heat pipes to conduct heat away from the CPU, and air-conditioning system commonly use heat pipes for heat conduction.

The principle behind heat pipe's operation is actually very simple.



Structure and Principle

The heat pipe is hollow with the space inside evacuated, much the same as the solar tube. In this case insulation is not the goal, but rather to alter the state of the liquid inside. Inside the heat pipe is a small quantity of purified water and some special additives. At sea level water boils at 100°C (212°F), but if you climb to the top of a mountain the boiling temperature will be less that 100°C (212°F). This is due to the difference in air pressure.

Based on this principle of water boiling at a lower temperature with decreased air pressure, by evacuating the heat pipe, we can achieve the same result. The heat pipes used in AP solar collectors have a boiling point of only 30°C (86°F). So when the heat pipe is heated above 30°C (86°F) the water vaporizes. This va pour rapidly rises to the top of the heat pipe transferring heat. As the heat is lost at the condenser (top), the va pour condenses to form a liquid (water) and returns to the bottom of the heat pipe to once again repeat the process.

At room temperature the water forms a small ball, much like mercury does when poured out on a flat surface at room temperature. When the heat pipe is shaken, the ball of water can be heard

Technical Info
Evacuated Tubes
Heat Pipes
Efficiency Calculations

Career Opportunities

EU Technical Team Position
Click here for details

FOLLOW US ON TWITTER

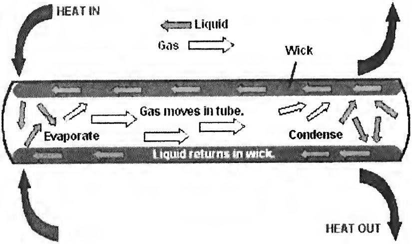
Around the network
BNET Go

close

Dictionary

Definition: heat pipe

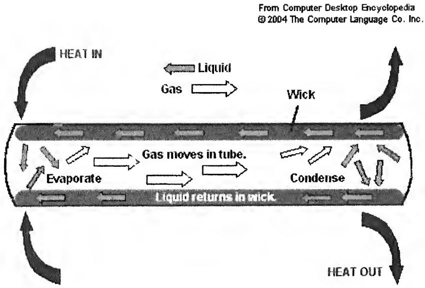
A tubular device that is very efficient in transferring heat. Using a metal container (aluminum, copper, etc.) that holds a liquid (water, acetone, etc.) under pressure, the inner surface of the tube is lined with a porous material that acts as a wick. When heat is applied to the outer area of the tube, the liquid inside the tube boils and vaporizes into a gas that moves through the tube seeking a cooler location where it condenses. Using capillary action, the wick transports the condensed liquid back to the evaporation area. See heat sink.



How It Works
A variety of liquids and wicks are used to make a heat pipe, but the principle is the same. The liquid evaporates into a gas that travels to the cooler end of the pipe, condenses back into liquid and returns via the wick.

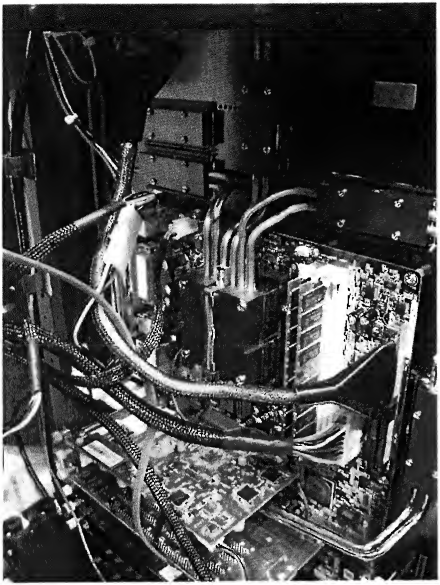
Appendix B

evaporation area. See heat sink.



How It Works
A variety of liquids and wicks are used to make a heat pipe, but the principle is the same. The liquid evaporates into a gas that travels to the cooler end of the pipe, condenses back into liquid and returns via the wick.

Appendix B



A CPU Cooler
In this high-end TNN500A computer cabinet from Zalman (www.zalmanusa.com), the heat pipe transfers the heat from the CPU to the wall of the case, which acts as a giant heat sink. This combination of heat pipe and case eliminates the need for a noisy fan.

Appendix B

Random Gallery Images

Title : How Does a Heat Pipe Work? Heat Pipes Explained
Author : Alan McCloskey
Date : Wednesday, August 15, 2007

0 0

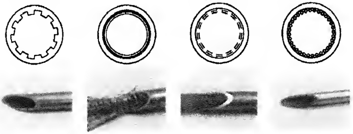
Heat Pipes Explained

A heat pipe is a heat transfer mechenism that can transport large quantities of heat with a very small difference in temperature between the hot and cold interfaces.

Heat pipes are extensively used in many modem computer systems, where increased power requirements and subsequent increases in heat emission have resulted in greater demands on cooling systems. Heat pipes are typically used to move heat away from components such as CPUs and GPUs to heat sinks where thermal energy may be dissipeted into the environment.

Construction
A typical heat pipe consists of a sealed hollow tube, which is made from a thermoconductive metal such es copper or aluminium. The pipe contains a relatively small quantity of "working fluid" (such as water, ethanol or mercury) with the remainder of the pipe being filled with vapor phase of the working fluid.

On the Internal side of the tube's side-walls e wick structure exerts a capillary force on the liquid phase of the working fluid. This is typically a sintered metal powder (sintering is a method for making objects from powder, by heating the material until its particles adhere to each other) or a series of grooves etched in the tube's inner surface. The basic idea of the wick is to soak up the coolant.



Appendix B

Heat pipes contain no moving parts and require no maintenance and are completely noiseless. In theory, it is possible that gasses mey diffuse through the pipe's walls over time, thus reducing this effeciveness.

The vast majority of heat pipes uses either ammonia or water as working fluid. Extreme applications may call for different materials, such as liquid helium (for low temperature applications) or mercury (for extreme high temperature applications).

The advantage of heat pipes is their great efficiency in transferring heat. They are ectually a better heat conductor than an mass of solid copper.

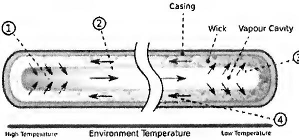
Wicking Material	Conductivity	Overcome Gravity	Thermal Resistance	Stability	Conductivity Lost
Axial Groove	Good	Poor	Low	Good	Average
Screen Mesh	Average	Average	Average	Average	Low
Fine Fiber	Poor	Good	High	Poor	Average
Sintering (powder)	Average	Excellent	High	Average	High

Mechanism

Heat pipes use evaporation and condensation to move heat quickly from one piece to another. A typical heat pipe is e sealed tube containing a liquid and a wick. The wick extends from one end of the tube to the other end is made of a material that attracts the liquid--the liquid "wets" the wick. The liquid is called the "working fluid" and is chosen so that it tends to be a liquid the temperature of the colder end of the pipe and tends to be a gas at the temperature of the hotter end of the pipe. Air is removed from the pipe so the only gas it contains is the gaseous form of the working fluid.

The pipe functions by evaporating the liquid working fluid into gas at its hotter end end allowing that gaseous working fluid to condense back into a liquid at its colder end. Since it takes thermal energy to convert a liquid to a ges, heet is ebsorbed at the hotter end. And because a gas gives up thermal energy when it converts from a ges to a liquid, heat is released at the colder end.

After a brief start-up period, the heat pipe functions smoothly as a rapid conveyor of heat. The working fluid cycles around the pipe, evaporating from the wick at the hot end of the pipe, traveling es e gas to the cold end of the pipe, condensing on the wick, end then traveling as a liquid to the hot end of the pipe.



Heat pipe thermal cycle
1) Working fluid evaporates to vapour absorbing thermal energy.
2) Vapour migrates along cavity to lower temperature end.
3) Vapour condenses back to fluid and is absorbed by the wick, releasing thermal energy
4) Working fluid flows back to higher temperature end.

The vapor pressure over the hot liquid working fluid at the hot end of the pipe is higher then the vapour pressure over fluid at the cooler end of the pipe (where it condenses), and this pressure difference drives a rapid mass transfer to the condensing end where the excess vapour releases its latent heat, warming the cool end of the pipe. Non-condensing gases (caused by contamination for instance) in the vapour impede the gas flow, and reduce the effectiveness of the heat pipe, where vapor pressures are low.

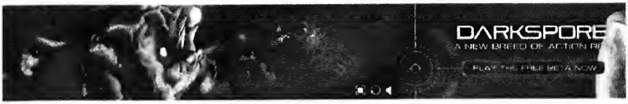
The condensed working fluid then flows back to the hot end of the pipe. In the case of vertically-oriented heat pipes the fluid may be moved by the force of gravity. In the case of heat pipes containing wicks, the fluid is returned by capillary action. Most heatpipes used in heatsinks today have wicks, and are effective in vertical or horizontal orientation.

In summary: Inside a heat pipe, "hot" vapor flows in one direction, condenses to the liquid phase, which flows back in the other direction to evaporate again and close the cycle.

Limitations

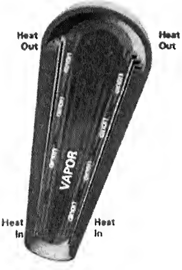
When heated above a certain temperature, all of the working fluid in the heat pipe will vaporize and the condensation process will cease to occur; in such conditions, the heat pipe's thermal conductivity is reduced to the heat conduction properties of its solid metal casing alone. As most heat pipes are constructed of copper, an overheated heatpipe will generally continue to conduct heat at only around 1/80th of their original conductivity.

Appendix B



How A Heat Pipe Works

12:00 PM - January 31, 2003 by Frank Völkel

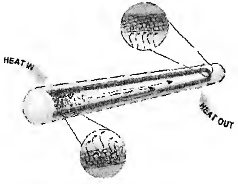


A cutaway diagram showing a heat pipe and how it works.

A heat pipe uses a hollow receptacle (metal pipe) to transport heat directly from one point to another. The metal pipe is filled with fluid, 90 percent of which is distilled water; the remainder consists of special ingredients added to optimize the liquid's thermal transfer properties. Here's how it works: the liquid is subjected to a very low pressure, reducing the evaporation point to approximately 30 degrees Celsius. When cold, the pipe contains very little water. However, when the heat pipe contacts the CPU directly on one end, the water evaporates and transports the thermal energy to the cold end of the pipe.

The difference in temperature between the two end depends on the fluid used and the length of the heat pipe. On average, though, the difference amounts to about eight degrees. One important factor impacting efficiency is the position of the pipe when it is installed - the end dissipating heat must always be placed higher than the one collecting heat from the CPU. A heat pipe works best when placed in a perfectly vertical position. The heat pipe Shuttle installs in its mini PCs is up to 95 percent efficient - the heat-absorbing and heat-dissipating ends are perpendicular to each other at different heights.

Appendix B



How a heat pipe works.

previous page How A Heat Pipe Works next page

Share Be the first to comment! |

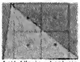
Recommend Be the first of your friends to recommend this.

Read More Mini

Subscribe to the Tom's Hardware Newsletter Enter your email here Submit

Featured Topics Latest News Forum


Low-Power Gaming: AMD's E-350 Vs. Intel Atom D525 And Ion 2


Anti-Aliasing Analysis, Part 1: Settings And Surprises


P67, X58, And NF200: The Best Platform For CrossFire And SLI


GeForce And Radeon On Intel's P67: PCIe Scaling Explored

Latest Desktops News

- 03/18 - The $500 Linux PC Aimed at Senior Citizens
- 03/12 - This Luxury PC Has Post-Modern Sculptural Look
- 02/17 - Smartphones Outsell PCs for the First Time Ever
- 02/14 - Sign Up, Comment Well, Win Core i7 Gaming Rig! Winner Picked,...
- 01/28 - Congratulations to Our Sandy Bridge PC Winner!

All Desktops news

Latest Desktops reviews

- 12/22 - Build It: Half-Height Gaming PCs For The Living Room
- 12/10 - Three Slim Atom/Ion 2-Based Nettop PCs Compared
- 09/02 - ASRock Core 100HT-BD Home Theater PC

All Desktops reviews

Comments

Comment:

Submit my comment

To See

Forum
Heat pipe how it works
How a pipe works
Heat pipe

More Topics

Others
Heat pipe luxman

Appendix B

- *Required*
    - Propulsion
    - Power
    - Thermal control
    - Communications
    - Attitude control
    - Computer(s) -- *aka Command and Data Handling*
    - Structure
    - Ground control (not physically part of a satellite but necessary for its operation!)
- *Optional*
    - Scientific instruments
    - Environmental Control and Life Support

Propulsion

- Usually s/c launched onto orbit or trajectory so that gravity everything needed to keep it moving
- To *change* to different orbit or trajectory, must used rocekts to add another force
- Conventional methods (propulsion)
- Solar sails
    - Would use large (1 sq. km.) reflective sail (made of thin plastic)
    - Light pushes on the sail to provide necessary force to change orbit
    - Still on the drawing board, but technologically possible!

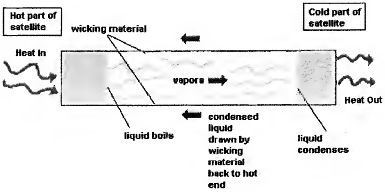
Power

- Cars and aircraft generate electrical power from their engines, but s/c engine not always on
- Need power for communications, computers, scientific instruments, environ. control and life support, thermal control, and even for propulsion (to start the rocket engine)
- **Batteries** used to *store* electrical energy
- **Solar cells** (photovoltaic cells) convert sunlight energy directly into electrical energy
    - solar cells at best only 20% efficient (i.e., 80% of the sunlight striking the cells is lost as heat)
    - s/c sometimes in shadow of Earth, so must use a combination of solar arrays (large sets of solar cells) and rechargeable batteries
- **RTG's** -- Radioisotope Thermoelectric Generators -- convert heat from decaying radioisotope (usually plutonium) directly into electrical power -- only about 7% efficient, so 93% of the heat is lost (or can be used to heat a cold part of the s/c) -- RTG's used for s/c moving *away* from the Sun (Mars close enough to use solar cells, but RTG's need for Jupiter and beyond)

Thermal control

- Side of s/c facing Sun gets very hot (no breezes to cool it off)
- Side of s/c facing away fro mSun gets very cold (no warm atmosphere around it to keep it warm
- **Passive control** (no power)
    - White paint or reflective coating on sunlit side
    - Low-emission coatings on shadow side (so s/c will not radiate so much heat away
    - Insulation blankets -- multi-layer insulation (MLI) -- many layers of light-weight material that conducts heat very poorly
    - Heat pipes -- conduct heat from hot part(s) of satellite to cold part(s). A heat pipe consists of a sealed pipe (can be almost any size or length, and can go around corners) containing a liquied that boils at a relatively low temperature. At the hot end of the satellite, heat enters the heat pipe and causes the liquid at that end to boil (see figure). The resulting vapors expand into the pipe, carrying that heat. When they reach the cold end of the satellite, the vapors condense back into a liquid, releasing the heat, which then flows out of the pipe to warm that part of the satellite. Inside the pipe, a thin layer of wicking material (something absorbent

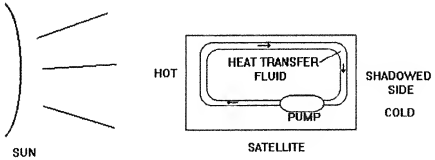
like a paper towel) draws the liquid back along the pipe to the beginning point, where the cylcle is repeated.



Heat Pipe

Heat pipes are the most efficient way to carry heat -- they use no electrical power, and will operate indefinitely since there are no mechanical parts to wear out.

- **Active control** (uses power)
  - Heating coils (like in a toaster) to warm up cold parts (some propellants freeze easily)
  - Use special cooling systems on hot parts



Communications

- Radios (several for redundancy)
  - voice communications if humans onboard
  - data sent back to Earth from scientific instruments
  - instructions sent to s/c from Earth
- Video (pictures of Earth, stars, other planets, etc.)
- various antennas: dish, dipole, helix

Attitude sensing and control (orientation of s/c)

Appendix B

Latest Content
Latest Community Postings
Recent Blog Entries
Community Downloads
ChExpress Blog
Ankur's Tech Blog
Community Admin Blog
Energy Efficient Hot and Cold Water
Electrical Process Tomography
Biodiesel: The Road Ahead
Methanol Plant Capacity Enhancement
Plate and Frame Heat Exchangers: Preliminary Design
Compressor Surging Under Control
Plant and Equipment Wellness, Part 1: Observing Variability

What is a Heat Pipe?

Introduction

A heat pipe is a simple device that can quickly transfer heat from one point to another. They are often referred to as the "superconductors" of heat as they possess an extra ordinary heat transfer capacity & rate with almost no heat loss.

The idea of heat pipes was first suggested by R.S.Gaugler in 1942. However, it was not until 1962, when G.M.Grover invented it, that its remarkable properties were appreciated & serious development began.

It consists of a sealed aluminum or copper container whose inner surfaces have a capillary wicking material. A heat pipe is similar to a thermosyphon. It differs from a thermosyphon by virtue of its ability to transport heat against gravity by an evaporation-condensation cycle with the help of porous capillaries that form the wick. The wick provides the capillary driving force to return the condensate to the evaporator. The quality and type of wick usually determines the performance of the heat pipe, for this is the heart of the product. Different types of wicks are used depending on the application for which the heat pipe is being used.

Design Considerations

The three basic components of a heat pipe are:

1. the container
2. the working fluid
3. the wick or capillary structure

Container

The function of the container is to isolate the working fluid from the outside environment. It has to therefore be leak-proof, maintain the pressure differential across its walls, and enable transfer of heat to take place from and into the working fluid.

Appendix B

Selection of the container material depends on many factors. These are as follows:

- Compatibility (both with working fluid and external environment)
- Strength to weight ratio
- Thermal conductivity
- Ease of fabrication, including welding, machineability and ductility
- Porosity
- Wettability

Most of the above are self-explanatory A high strength to weight ratio is more important in spacecraft applications. The material should be non-porous to prevent the diffusion of vapor. A high thermal conductivity ensures minimum temperature drop between the heat source and the wick.

Working fluid

A first consideration in the identification of a suitable working fluid is the operating vapour temperature range. Within the approximate temperature band, several possible working fluids may exist, and a variety of characteristics must be examined in order to determine the most acceptable of these fluids for the application considered. The prime requirements are:

- compatibility with wick and wall materials
- good thermal stability
- wettability of wick and wall materials
- vapor pressure not too high or low over the operating temperature range
- high latent heat
- high thermal conductivity
- low liquid and vapor viscosities
- high surface tension
- acceptable freezing or pour point

The selection of the working fluid must also be based on thermodynamic considerations which are concerned with the various limitations to heat flow occurring within the heat pipe like, viscous, sonic, capillary, entrainment and nucleate boiling levels.

In heat pipe design, a high value of surface tension is desirable in order to enable the heat pipe to operate against gravity and to generate a high capillary driving force. In addition to high surface tension, it is necessary for the working fluid to wet the wick and the container material i.e. contact angle should be zero or very small. The vapor pressure over the operating temperature range must be sufficiently great to avoid high vapor velocities, which tend to setup large temperature gradient and cause flow instabilities.

A high latent heat of vaporization is desirable in order to transfer large amounts of heat with minimum fluid flow, and hence to maintain low pressure drops within the heat pipe. The thermal conductivity of the working fluid should preferably be high in order to minimize the radial temperature gradient and to reduce the possibility of nucleate boiling at the wick or wall surface. The resistance to fluid flow will be minimized by choosing fluids with low values of vapor and liquid viscosities. Tabulated below are a few mediums with their useful ranges of temperature.

MEDIUM	***MELTING PT. (°C)***	***BOILING PT. AT ATM. PRESSURE (°C)***	***USEFUL RANGE (°C)***
Helium	- 271	- 261	-271 to -269

Appendix B

Nitrogen	- 210	- 196	-203 to -160
Ammonia	- 78	- 33	-60 to 100
Acetone	- 95	57	0 to 120
Methanol	- 98	64	10 to 130
Flutec PP2	- 50	76	10 to 160
Ethanol	- 112	78	0 to 130
Water	0	100	30 to 200
Toluene	- 95	110	50 to 200
Mercury	- 39	361	250 to 650
Sodium	98	892	600 to 1200
Lithium	179	1340	1000 to 1800
Silver	960	2212	1800 to 2300

Wick or Capillary Structure

It is a porous structure made of materials like steel, alumunium, nickel or copper in various ranges of pore sizes. They are fabricated using metal foams, and more particularly felts, the latter being more frequently used. By varying the pressure on the felt during assembly, various pore sizes can be produced. By incorporating removable metal mandrels, an arterial structure can also be molded in the felt.

Fibrous materials, like ceramics, have also been used widely. They generally have smaller pores. The main disadvantage of ceramic fibres is that, they have little stiffness and usually require a continuos support by a metal mesh. Thus while the fibre itself may be chemically compatible with the working fluids, the supporting materials may cause problems. More recently, interest has turned to carbon fibres as a wick material. Carbon fibre filaments have many fine longitudinal grooves on their surface, have high capillary pressures and are chemically stable. A number of heat pipes that have been successfully constructed using carbon fibre wicks seem to show a greater heat transport capability.

The prime purpose of the wick is to generate capillary pressure to transport the working fluid from the condenser to the evaporator. It must also be able to distribute the liquid around the evaporator section to any area where heat is likely to be received by the heat pipe. Often these two functions require wicks of different forms. The selection of the wick for a heat pipe depends on many factors, several of which are closely linked to the properties of the working fluid.

The maximum capillary head generated by a wick increases with decrease in pore size. The wick permeability increases with increasing pore size. Another feature of the wick, which must be optimized, is its thickness. The heat transport capability of the heat pipe is raised by increasing the wick thickness. The overall thermal resistance at the evaporator also depends on the conductivity of the working fluid in the wick. Other necessary properties of the wick are compatibility with the working fluid and wettability.

The most common types of wicks that are used are as follows:

Sintered Powder

This process will provide high power handling, low temperature gradients and high capillary forces for anti-gravity applications. The photograph shows a complex sintered wick with several vapor channels and small arteries to increase the liquid flow rate. Very tight bends in the heat pipe can be achieved with this type of structure.

Grooved Tube

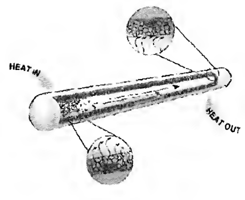
The small capillary driving force generated by the axial grooves is adequate for low power heat pipes when operated horizontally, or with gravity assistance. The tube can be readily bent. When used in conjunction with screen mesh the performance can be considerably enhanced.

Screen Mesh

This type of wick is used in the majority of the products and provides readily variable characteristics in terms of power transport and orientation sensitivity, according to the number of layers and mesh counts used.

Working

Inside the container is a liquid under its own pressure, that enters the pores of the capillary material, wetting all internal surfaces. Applying heat at any point along the surface of the heat pipe causes the liquid at that point to boil and enter a vapor state. When that happens, the liquid picks up the latent heat of vaporization. The gas, which then has a higher pressure, moves inside the sealed container to a colder location where it condenses. Thus, the gas gives up the latent heat of vaporization and moves heat from the input to the output end of the heat pipe.



Heat pipes have an effective thermal conductivity many thousands of times that of copper. The heat transfer or transport capacity of a heat pipe is specified by its " Axial Power Rating (APC)". It is the energy moving axially along the pipe. The larger the heat pipe diameter, greater is the APR. Similarly, longer the heat pipe lesser is the APR. Heat pipes can be built in almost any size and shape.

Applications

Heat pipe has been, and is currently being, studied for a variety of applications, covering almost the entire spectrum of temperatures encountered in heat transfer processes. Heat pipes are used in a wide range of products like air-conditioners, refrigerators, heat exchangers, transistors, capacitors, etc. Heat pipes are also used in laptops to reduce the working temperature for better efficiency. Their application in the field of cryogenics is very significant, especially in the development of space technology. We shall now discuss a brief account of the various applications of heat pipe technology.

Space Technology

The use of heat pipes has been mainly limited to this field of science until recently, due to cost effectiveness and complex wick construction of heat pipes. There are several applications of heat pipes in this field like

- Spacecraft temperature equalization
- Component cooling, temperature control and radiator design in satellites.
- Other applications include moderator cooling, removal of heat from the reactor at emitter temperature and elimination of troublesome thermal gradients along the emitter and collector in spacecrafts.

Heat pipes for Dehumidification and Air conditioning

In an air conditioning system, the colder the air as it passes over the cooling coil (evaporator), the more the moisture is condensed out. The heat pipe is designed to have one section in the warm incoming stream and the other in the cold outgoing stream. By transferring heat from the warm return air to the cold supply air, the heat pipes create the double effect of pre-cooling the air before it goes to the evaporator and then re-heating it immediately.

Activated by temperature difference and therefore consuming no energy, the heat pipe, due to its pre-cooling effect, allows the evaporator coil to operate at a lower temperature, increasing the moisture removal capability of the air conditioning system by 50-100%. With lower relative humidity, indoor comfort can be achieved at higher thermostat settings, which results in net energy savings. Generally, for each 1° F rise in thermostat setting, there is a 7% savings in electricity cost. In addition, the pre-cooling effect of the heat pipe allows the use of a smaller compressor.

Laptop Heat Pipe Solution

Heat pipe technology originally used for space applications has been applied it to laptop computer cooling. It is an ideal, cost effective solution. Its light weight (generally less than 40 grams), small, compact profile, and its passive operation, allow it to meet the demanding requirements of laptops.

For an 8 watt CPU with an environmental temperature no greater than 40°C it provides a 6.25°

Appendix B

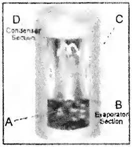
Heat Pipe Technology, Inc
Advanced Dehumidification & Energy Recovery

4340 N.E. 49th Avenue
Gainesville, FL 32609
Tel. (352) 367-0999
Fax: (352)367-1688
Email: heatpipe@heatpipe.com

What are Heat Pipes?

Heat Pipe are thermal transfer divices that are cepable of transfering heat seval hundred times faster than conventional methods.

Heat Pipe Structure. A traditional heat pipe is a hollow cylinder filled with a vaporizable liquid.



A. Heet is absorbed in the evaporating section.

B. Fluid boils to vapor phase.

C. Heat is released from the upper part of cylinder to the environment; vapor condenses to liquid phase

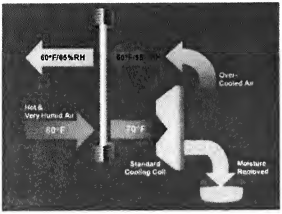
D. Liquid returns by gravity to the lower part of cylinder (evaporating section)

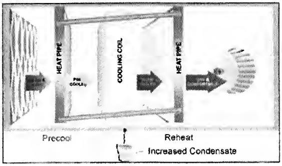
Using Heat Pipes to Improve Dehumidification

Heet pipes may be described as having two sections: ***precool*** and ***reheat***. The first section is located in the incoming air stream. When warm air passes over the heat pipes, the refrigerent vaporizes, carrying heat to the second section of heat pipes, placed downstream. Because some heat has been removed from the air before encountering the evaporator coil, the incoming eir stream section is called the **precool heat pipe**.

Air pessing through the eveporator coil is assisted to e lower tempereture, resulting in greater condensate removal. The "overcooled" air is then reheated to a comfortable tempereture by the **reheat heat pipe section**, using the heat transferred from the precool heat pipe.

This entire process of precool and reheat is accomplished with no additional energy use The result is an air conditioning system with the ability to remove 50 to 100% more moisture than reguler systems.

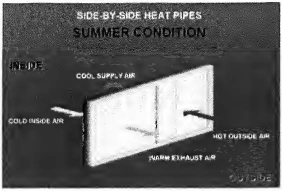


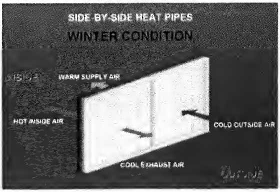


Using Heat Pipes for Energy Recovery from Exhaust Air to Supply Air

Energy Recovery Heat Pipes from HPT provide economical and reliable recovery of both heat end cooling. Traditional heat pipes normally transfer heat in one direction during the heeting season end the opposite direction during the cooling season, they heve been equipped with a tilting mechanism. HPT has developed Heat Pipes with patented circuital loops in a 3-D (three-dimensional) configuration. The Heat Pipe fluid moves in a continuous one directional flow through the individual three-dimensional circuits. This avoids the need for a tilting mechanism.

Appendix B


SIDE-BY-SIDE HEAT PIPES
SUMMER CONDITION
COOL SUPPLY AIR
COLD INSIDE AIR
HOT OUTSIDE AIR
WARM EXHAUST AIR


SIDE-BY-SIDE HEAT PIPES
WINTER CONDITION
WARM SUPPLY AIR
HOT INSIDE AIR
COLD OUTSIDE AIR
COOL EXHAUST AIR

Appendix B